Power Electronics

Power electronics, in general terms, is defined as the use of switching devices to control and convert electrical power flow from one form to another to meet a user's need. "Convert" is a general term used in power electronics to describe the process of changing power from one form to another. The hardware that performs the process is generally called the "converter." Converters can perform the following processes/conversions (when each process/conversion is performed, the hardware is referred to with a particular name):

Conversion	Common Names
AC-to-DC	Rectifier
DC-to-AC*	Inverter
DC-to-DC	"boost," "buck," "buck-boost," "chopper," etc.
AC-to-AC	**"cycloconverters"**

*The most common type of conversion is DC-to-AC (inversion); e.g., converting DC power from a storage device into AC power for use by a utility grid or other end-user.

Performing the conversions requires some essential hardware: a control system, semiconductor switches, thermal management devices, protection devices, magnetics such as transformers and filters, DC and AC disconnects, and enclosures. Taken together, this hardware is referred to as the power conversion system (PCS).

Power Conversion Systems (PCS)

The PCS is a vital part of all energy storage systems. It interfaces the energy storage, the energy storage device and the load (the end-user). PCS cost is significant and it can be greater than 25% of the overall energy storage system. PCS cost range from $100/kW for UPS markets to $1200/kW for Standalone markets have been seen. Some of the major PCS markets include:

- motor drives
- power supplies
- UPS (uninterruptible power supply)
- electric vehicles
- inverters/converters for solar-hybrid systems, micro-turbines, fuel cells, wind turbines

However, PCS technology has been evolving slowly due to the limited DER market. As a result, PCS cost has been high with low profit margins and the manufacturing volume has been low impacting reliability and quality of the PCS designs. What is needed is a significant reduction in overall cost with improved reliability, development of state-of-the-art PCS with multiple uses, which increases production volumes for DER applications, improve controls and adaptability, and improve manufacturing.

DOE Energy Storage Systems Program Involvement

Sandia, representing DOE's Energy Storage Systems Program (ESSP), is partnering with industry and educational institutions to develop state-of-the-art PCS. This includes lower cost, increasing reliability, improved control philosophy, better integration to energy storage devices, and more efficient packaging and manufacturing for the PCS. Such efforts by the ESSP are instrumental in providing benefits for all energy users and helping to secure our nation's energy supply.

Current PCS projects include:

Project	Description	Partner(s)
ETO (Emitter Turn-Off)-based converter switch for energy storage systems	Development of a low cost/highly reliable/low footprint ETO-based converter for high power utility applications	Concept/prototype: Virginia Tech Manufacturability: American Competitiveness Institute (ACI) Testing: Navy Surface Warfare Center and Tennessee Valley Authority
Alternative RGS System Designs to Improve Battery Performance	Develop and validate integrated devices that will improve system reliability and component performance, and reduce the life-cycle-costs of continuous power systems, such as renewable generation systems (RGS).	Electrochemical Engineering Consultants, Inc. (EECI)
Integration & Testing of Energy Storage with Flexible AC Transmission System (FACTS) Devices	Exploration of the operational enhancement of a power transmission system by integrating a battery energy storage system (BESS) into a variety of Flexible AC Transmission System (FACTS) devices.	University of Missouri at Rolla
Hardware Prototype of Device to Improve Transient Loadability of Distributed Energy Resources (DER)	Development of a laboratory prototype for an energy storage-based device that will improve transient loadability of Distributed Energy Resources (DER)	New Mexico State University (NMSU)
Optically Isolated Inverters for DER Applications	Development of the first optically isolated/interconnected, high-power, cascaded inverter for Distributed Energy Resource applications, based upon recent advances in optical sensors, optical interconnects, and High-Voltage Integrated Gate Bipolar Transistors (HV-IGBT).	Airak, Inc.

Sandia National Laboratories maintains an extensive technical library of publications that detail ESS involvement in PCS. For example: SAND98-2019 — *Summary of State-of-the-Art Power Conversion Systems for Energy Storage Applications*
http://infoserve.sandia.gov/sand_doc/1998/982019.pdf

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